



Determining eye-hand co-ordination using the sport vision trainer (SVT™): an evaluation of test-retest reliability

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3 1 Determining eye-hand co-ordination using the sport vision trainer (SVT™): an
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6 evaluation of test-retest reliability

7 3 Abstract

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9 4 *Objectives:* The purpose of this investigation was to assess the number of test-retest
10 5 trials required to familiarise participants in order to provide acceptable reliability for
11 6 the measurement of an eye-hand co-ordination task using the Sport Vision Trainer
12 7 (SVT™). *Design:* Two schedules were conducted (S1 and S2); *Methods:* (S1): Sixty-
13 8 four participants (male n=51, age 20.8±4.9 years; female n=13, age 20.1±2.1years)
14 9 attended four sessions each one week apart, and undertook four trials using the
15 10 SVT™. (S2): Sixty participants (male n=46, age 20.8±4.9 years; female n=14, age
16 11 20.1±2.1 years) attended one 20-minute schedule consisting of four consecutive
17 12 trials using the SVT™. *Results:* Limits of agreement (LoA) analyses showed that
18 13 absolute reliability was increased in both studies. The LoA for S2 indicate that error
19 14 decreased between trial 1-2, 2-3, and 3-4; ±0.95 (CI,-1.16,+2.56sec), ±0.97 (CI,-
20 15 1.66,+2.14sec), ±0.69 (CI,-1.08,+1.62sec). *Conclusion:* Reliable measurements of
21 16 eye-hand co-ordination can be obtained using the SVT™ in one session.

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19 Keywords: Psychomotor Performance; Visual Motor Co-ordination; Reliability of
20 Results; Reaction Time; Test-Retest Reliability

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3 22 Introduction
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5 23 The visual system plays a critical role in sports performance (Williams, Davids, &
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7 24 Williams, 2005), as it does in the performance of virtually all perceptual-motor skills
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9 25 (Paillard, 1990). To advance sports performance through improving vision an
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11 26 understanding of the visual demands of different sports is required. Evaluation of the
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13 27 degree that varying visual parameters can be adapted through the training of visual
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15 28 abilities also needs to be considered. Eye-hand co-ordination is a crucial aspect of
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17 29 sport performance as decisions frequently need to be made very quickly based on
18
19 30 the presentation of a wide range of visual stimuli. Eye-hand co-ordination also plays
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21 31 an integral role in sports vision and has been researched in many sport contexts
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23 32 such as goalkeeping in soccer (Nagano, Kato, & Fukuda, 2004), defence in
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25 33 basketball (Laurent, Ward, Williams, & Ripoll, 2006), and general passing, and
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27 34 throwing and hitting in other sports (Zupan, Arata, Wile, & Parker, 2011). Despite this
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29 35 there are currently no recognised standardised measurements for testing eye-hand
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31 36 co-ordination in sport. Traditionally researchers have used non-validated tools, or
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33 37 ones with little established accuracy (Du Toit et al., 2011). The development of a
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35 38 reliable measurement tool would therefore provide athletes and coaches with an
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37 39 effective evaluation device for improving sport performance. The Sport Vision Trainer
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39 40 (SVT™) has the potential to be such a device. The SVT™ 32 sensor pad is
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41 41 a portable system developed for teams/practitioners who want to use the SVT™
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43 42 in different locations. It can also be used either in landscape or portrait positions to
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45 43 portray both the proactive and reactive eye-hand co-ordination demands of many
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47 44 sports.
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49 45 Practically, some amount of biological error is always present with continuous
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51 46 measurements (Hopkins, 2000). Therefore reliability could be considered as the
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3 47 amount of measurement error that has been deemed satisfactory for the successful
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5 48 practical use of a measurement device. The publication of data for reliability studies
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7 49 has been acknowledged to considerably enhance comparisons of the consistency of
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9 50 testing and equipment (Hopkins, 2000). Consequently practitioners can be assured
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11 51 that any improvement in performance is due to interventions introduced and eliminate
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13 52 potential differences in gender, experience, and any familiarisation effect of the
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15 53 SVT™ as a factor. Currently there are no studies that assess the test-retest reliability
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17 54 of the SVT™. Therefore, the purpose of this investigation was to assess the **number**
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19 55 **of test-retest trials required using the SVT™ to familiarise participants in order to**
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21 56 **provide acceptable reliability for the measurement of an eye-hand co-ordination task.**
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23 57 The second purpose of this investigation was to determine **if a shorter schedule of**
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25 58 **familiarisation could be used to assist the researcher in a more appropriate, timely**
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27 59 **collection period.**
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31 Methods

32 Research Design

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34 62 Prior to testing all procedures were described and a full demonstration was given to
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36 63 the participants in order to give them an idea of the testing protocol without them
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38 64 actually using the SVT™ before any familiarisation session taking place. Two
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40 65 schedules were then carried out. **The same investigator was responsible for data**
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42 66 **collection for both schedules. Data were recorded electronically via the SVT™ and**
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44 67 **automatically saved to an excel file.** The first schedule (S1) took place over a four
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46 68 week period based on recommendations to assess reaction times (Ando, Kida, &
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48 69 Oda, 2004). Once this had been completed a second period of data collection was
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50 70 undertaken (S2) with different participants to assess whether the same trials (T), as
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3 71 endorsed by the manufacturer of the equipment (Sports Vision, 2012), could be
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5 72 conducted in a shorter (approx. 20-minutes), and therefore more practical session.
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7 73 Participants

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9 74 Sixty-four sports participants (male n=51, Female n=13) volunteered for S1 and sixty
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11 75 (male n=46, female n=14) for S2. The participants were of mixed abilities ranging
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13 76 from collegiate to national standard in a variety of team and individual sports.
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15 77 Records of the experience (S1, 6.03±4.19yrs; S2, 6.21±3.73yrs) and hours of training
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17 78 per week (S1, 5.34±3.52hrs; S2, 5.88±4.27hrs) in the participants sport was
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19 79 obtained. Vision health questionnaires (Williams et al., 2005) were also completed to
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21 80 assess suitability for the study. Anyone who had suspected visual
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23 81 impairment/difficulties was referred to an optometrist. Participants exhibiting any
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25 82 visual deficiencies were excluded from participating and referred to an optician. Four
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27 83 participants (n=2 from S1, and n=2 from S2) were excluded from the final
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29 84 calculations. Any participant suffering shoulder, wrist or finger injury during the last
30
31 85 six months was excluded. All included participants reported normal visual acuity
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33 86 either unaided or while wearing their own corrective lenses. All experimental
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35 87 procedures were approved by the Institutional Ethics committee prior to testing. All
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37 88 participants were informed of the risks and procedures of the investigation prior to
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39 89 giving written informed consent.
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45 90 Testing Procedures

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47 91 In S1 participants subsequently completed four sessions of six trials using the SVT™
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49 92 32 sensor pad. This test is carried out on a display board (135 cm in length, 18 cm in
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51 93 width, and 60cms in height) with 32 touch-sensitive red light emitting diodes (LED's).
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53 94 All trials took place at the same time of day to avoid any effects of circadian
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55 95 variations (Atkinson & Reilly, 1996; Edwards, Waterhouse, & Reilly, 2008). Each
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3 96 session was separated by one week as reliability of cognitive variables have been
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5 97 shown to be highly reliably over a 4-week period (Wallman, Morton, Goodman, &
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7 98 Grove, 2005). The ambient light in the room was carefully controlled and set at 420
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9 99 Lux (Sport Vision, 2012) using a Lux light meter (CEM DT-1300, Shenzhen, China).
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11 100 The SVT™ was programmed to use a proactive mode (Sport Vision, 2012) which
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13 101 meant that lights stayed illuminated until the participant responds by hitting them.
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15 102 Participants were required to touch each light as quickly as possible. The SVT™
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17 103 programme waits until it has measured the response before switching on the next
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19 104 light. Participants stood directly in front of a panel of 32 lights which displayed a
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21 105 centrally programmed sequence of 20 lights (the centre 16 lights, 4 by 4 array) which
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23 106 randomly illuminated. The height of the top of the SVT™ from the floor was
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25 107 standardised at 1.77cm for men and 164.4cm for females (NHS, 2012) and was
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27 108 positioned in a landscape format. Time to hit the sequence of 20 lights was recorded
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29 109 in milliseconds. The SVT™ program randomised the target order and location for
30
31 110 every trial to ensure fair test comparisons between users. The first two trials of 20
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33 111 lights were practice runs and means of the last four measurement trials were
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35 112 displayed at the end of the each trial. In S2 the same protocol was adhered to,
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37 113 except the **six** trials were carried out with 10 second breaks, consecutively in one
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39 114 session lasting approximately 20-minutes.
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45 Statistical Analysis

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47 116 For both S1 and S2 comparisons were conducted on the dependent variable of mean
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49 117 task completion time over the last four trials, in seconds, for Session 1 versus
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51 118 Session 2, Session 2 versus Session 3, and Session 3 versus Session 4, using the
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53 119 software for the Hopkins reliability spread sheet (Hopkins, 2012). This generated
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55 120 **coefficients of variation (CV), intra-class correlation coefficients (ICC), Pearson**
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3 121 correlation coefficients (r), and standard errors of measurements (SEM) for each
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5 122 comparison as recommended for these types of investigations (Atkinson & Nevill,
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7 123 1998; Hopkins, 2000; Morrow & Jackson, 1993) (Table 2). To derive the within-
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9 124 subject variation expressed as a coefficient of variation (CV) all data was log-
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11 125 transformed in accordance with the methodology identified in Hopkins reliability
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13 126 spreadsheet (Hopkins, 2012), differences between trials were then calculated for
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15 127 each participant. Acceptable reliability was identified as being a CV <5% (Vincent
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17 128 2005) and ICC's >r=0.80, below which reliability has been suggested to be
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19 129 "questionable" (Atkinson and Nevill 1998). With three comparisons within each
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21 130 schedule, probability values for Pearson coefficients were evaluated against a
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23 131 Bonferroni adjusted alpha level of $P \leq .017$. Bland-Altman plots (Bland & Altman,
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25 132 1986) were used to describe the Limits of agreement (LoA) for each comparison
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27 133 within each schedule, following the method described by Atkinson and Nevill (1998).
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29 134 This generates 95% confidence intervals for differences in the performance of
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31 135 individuals across sessions in each comparison. Differences falling outside these
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33 136 confidence intervals may be regarded as random. A Kolmogorov-Smirnov test was
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35 137 conducted to test normality of data. Mann-Whitney's (Nachar, 2008) U test was
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37 138 conducted to evaluate the differences in performance between S1 and S2.
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39 139 Potential gender differences in performance were tested within each schedule,
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41 140 respectively, using a mixed between-within participants ANOVA, with gender as a
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43 141 between-participants independent variable and mean task completion times for
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45 142 Sessions 1 to 4 as a within-participants independent variable at four levels. Finally,
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47 143 the mean difference in participants' task completion times across all four trials was
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49 144 tested using schedule as a between-participants independent variable in a t-test. The
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51 145 suitability of these means for parametric analysis was established by graphical
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3 146 examination of their distribution and by statistical analysis of their skewness and
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5 147 kurtosis, as described by Tabachnick and Fidell (2001). There was no evidence to
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7 148 suggest that heteroscedasticity was present. All values presented are displayed as
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9 149 mean±standard deviation (SD), and a level of $p < 0.05$ was used to define statistical
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11 150 significance. All statistical procedures were conducted using SPSS17 statistical
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14 151 software (IBM, Chicago, USA).

152 Results

153 Acceptable reliability was observed following the completion of four trials in both
154 schedules. All trials demonstrated a reduction in the CV, SEM and ICC across the
155 trial comparisons from T1-2 to T3-4 (Table 1 and Table 2 for mean performance
156 times and reliability measurements, respectively). Pearson's r revealed no significant
157 relationship between experience and difference in means between T1 and T4 for
158 both studies: S1, $r(64) = 0.128$, $P = 0.352$; S2, $r(60) = -0.103$, $P = 0.432$. Pearson's
159 correlation revealed no significant relationship between training hours per week and
160 difference in means between T1 and T4 for both studies: S1, $r = -0.106$, $P = 0.452$; S2,
161 $r = -0.011$, $P = 0.931$. There was no significant differences in participants' task
162 completion times across all four sessions: $t(122) = 1.906$, $P = 0.059$, two-tailed. There
163 was no significant effect of groups between test schedules (The mean ranks of S1
164 and S2 were 68.11 and 156.52, respectively; $n = 64$, $n = 60$, $U = 1561$, $p < 0.072$, two
165 tailed). A significant main effect for gender was observed for the mean task
166 completion times between trial 1-4 in S1: $F_{(1,62)} = 4.828$, $P = 0.03$, $\eta^2 = 0.07$, $CI = 10.52$ -
167 11.33, and no significant main effect for gender for the mean task completion times
168 between trial 1-4 in S2: $F_{(1,58)} = 2.079$, $P = 0.16$, $CI = 10.39$ -11.26. In S1 a significant
169 main effect was observed for trial (Greenhouse-Geisser adjustments utilised):
170 $F_{(2.596, 160.958)} = 29.574$, $P = 0.001$, $\eta^2 = 0.323$ (Table 2). In S2 a significant main effect

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3 171 was observed for trial (Greenhouse-Geisser adjustments utilised):
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5 172 $F_{(2.52, 146.163)}=21.987$, $P=0.001$ (Table 2).
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10 174 The LoA analysis (Figure 1) shows that absolute reliability is increased from T1-T2 to
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12 175 T3-T4 in both studies. Improved LoA was observed between the four trials (trial 1-2,
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14 176 trial 2-3, and trial 3-4) for S1: ± 1.11 (CI, -1.37, +2.99 sec), ± 1.07 (CI, -1.76, +2.44
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16 177 sec), ± 0.74 (CI, -1.04, +1.86 sec), and S2: ± 0.97 (CI, -1.16, +2.56 sec), ± 0.95 (CI, -
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18 178 1.66, +2.14 sec), ± 0.69 (CI, -1.08, +1.62 sec) respectively. Pearson's r value also
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20 179 indicated an increasingly strong relationship from trial 2-1 to trial 4-3 in both
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22 180 schedules (Table 2).
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25 181 Discussion

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27 182 The purpose of this investigation was to assess the number of test-retest trials
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29 183 required to familiarise participants in order to provide acceptable reliability for the
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31 184 measurement of an eye-hand co-ordination task using the Sport Vision Trainer
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33 185 (SVT™). Furthermore a second testing protocol was conducted in order to
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35 186 determine if a more logistically practical schedule of familiarisation could be achieved
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37 187 with the same number of test-retest trials. As far as can be ascertained, there is no
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39 188 current research evaluating the SVT™, or using it as a research tool, despite existing
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41 189 evidence of effects of influences of familiarisation (Duncan, Al-Nakeeb & Nevill,
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43 190 2005). The design and analysis of this study factored in a random participants
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45 191 sample identified using recommended methods for assessing reliability in sports
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47 192 medicine based research (Atkinson & Nevill, 2001). In turn this enabled a precise
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49 193 estimate of measurement error parameters (CV; ICC and SEM) which was used to
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51 194 determine whether the SVT™ was acceptable for use in the simplest experimental
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53 195 setting (i.e. same experimenter and identical equipment). Random error was shown
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3 196 to reduce in all measurement error parameters as more tests were administered, until
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5 197 acceptable reliability was deemed satisfactory using ICC. These were interpreted as
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7 198 0.70-0.80 acceptable, 0.80-0.89 strong and 0.90-1.0 high correlation (Vincent, 2005).
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9 199 S1 identified an ICC of 0.87 (T3-4) and S2 0.89 (T3-4) respectively. Although the
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11 200 present study showed a significant difference in results between gender in S1, the
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13 201 effect size was small, and should be viewed with caution. There was no significance
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15 202 displayed for gender in S2 supporting previous research on eye-hand visual reaction
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17 203 times (Akarsu, Çaliskan, & Dane, 2009; Dane & Erzurumluoğlu, 2003) using a
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19 204 software package of random stimulus presentation. Applying the protocol outlined in
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21 205 S1 would take 4 weeks to complete; we therefore shortened the protocol (S2) into
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23 206 one testing session to see if **acceptable** reliability could be achieved in a more
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25 207 optimally practical testing duration. **The results for S2 showed similar values to S1**
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27 208 **allowing testing to take place in a shorter timeframe.** CV's of 4.94% and 4.76% for
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29 209 trials 3-4 in both S1 and S2 respectively identified (Vincent, 2005) (<5%) findings as
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31 210 an acceptable figure for reliability.

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36 211 As previous measures of **eye-hand** co-ordination and reaction in a sporting context
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38 212 have generally used non-validated tools, the development of a reliable training aid is
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40 213 highly relevant. Consequently this may provide athletes and practitioners with an
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42 214 effective tool for improving sports performance through increasing eye-hand co-
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44 215 ordination. The results also showed no significant relationships between experience,
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46 216 training hours and abilities offering the prospect of using the SVT™ for different
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48 217 populations using this familiarisation strategy. For example, although the present
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50 218 study focused on its use from a sporting perspective, these findings may present
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52 219 opportunities to use the SVT™ in improving **eye-hand co-ordination in general**
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54 220 **training** and other specialised instances (e.g. rehabilitation of motor dysfunction,

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3 221 visual deficiencies injury rehabilitation process, alternative to physical activities
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5 222 during recovery). Minimal measurement error during the collection of interval-and-
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7 223 ratio-type data has been identified as critically important for the assessment of
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9 224 performance (Atkinson & Nevill, 1998). Practically, as some amount of biological error
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11 225 is always present with continuous measurements, reliability in this study was
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13 226 considered as the amount of measurement error that has been deemed satisfactory
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16 227 for the successful practical use of the SVT™.

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18 228 The findings also suggest that using the shorter **schedule** outlined in S2 may allow
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20 229 future researchers to minimise familiarisation testing time and to condense a
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22 230 potentially time constraining activity to less than 20-minutes. The data is reflective
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24 231 and of the same magnitude as would typically be expected for the current population
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26 232 (Chang, Labban, Gapin, & Etnier, 2012). In order for future research on the validity of
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28 233 the SVT™ to be carried out it is important that the values indicated from repeated
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30 234 measurements are sufficiently meaningful. The 95% confidence intervals indicate
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32 235 that in all instances the change in CV is likely to be real for both **schedules** tested in
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34 236 the present study. **Future research should be conducted to determine whether skills**
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36 237 **learned on the SVT™ can be transferred into other contexts (e.g., improved sport**
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38 238 **performance, functional movements, rehabilitation outcomes). The SVT™ lends itself**
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40 239 **to the investigation of various elements impacting upon eye-hand co-ordination (e.g.:**
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42 240 **nutritional interventions, fatigue, environmental conditions, stimulus characteristics).**
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44 241 **Of particular interest is how different training approaches may impact upon the**
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46 242 **effective development of eye-hand co-ordination as measured using the SVT™ (e.g.,**
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48 243 **instructional approaches, practice schedules, implicit and explicit learning, and**
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50 244 **performance under pressure). Such studies using the SVT™ may provide athletes**
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52 245 and practitioners with an effective tool for improving sports performance. **A key**

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3 246 limitation of the present study is the use of a relatively typical sample of healthy
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5 247 young adults, and as such the data presented here may not transfer to other
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7 248 populations (e.g., individuals with cognitive and physical impairments). Therefore,
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9 249 future research using the SVT™ as a measure of eye-hand co-ordination in such
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11 250 populations should consider the assessment of effective familiarisation strategies.

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14 251 When investigating healthy populations, it is recommended that practitioners using
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16 252 the SVT™ should include the protocol (S2) described in the present paper to inform
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18 253 future interventions to eliminate any residual learning effects.

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21 254 Conclusion

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23 255 To our knowledge this is the first study to identify and analyse the reliability of test-
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25 256 retest familiarisation trials for the SVT™. In summary the findings of the study
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27 257 indicate that the familiarisation trials were statistically reliable over a four week
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29 258 period, and in a shorter 20-minute consecutive session. The shorter familiarisation
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31 259 protocol ensures that the logistics of testing are simplified for practitioners whilst also
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33 260 providing acceptable test-retest reliability. These results suggest that researchers
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35 261 may use the SVT™ for a range of potential training approaches and intervention
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37 262 studies. In order for future research on the validity of the SVT™ to be carried out it is
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39 263 important that the values indicated from repeated measurements are sufficiently
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41 264 meaningful. It can therefore be concluded that reliable measurements of eye-hand
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43 265 co-ordination can be obtained in one short session using the SVT™, providing four
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45 266 familiarisation sessions of six trials have taken place following description and a full
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47 267 demonstration of the procedure.

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Tables

Table 1. Descriptive statistics of mean performance times achieved in each Schedule (mean ± SD)

Participants	Age (yrs)	T1		T2		T3		T4	
		Mean* (s)	Threshold*(s)	Mean(s)	Threshold(s)	Mean(s)	Threshold(s)	Mean(s)	Threshold(s)
M (n=51)	20.8±4.9	11.39±1.57	0.56±0.07	10.53±1.55	0.52±0.07	10.2±1.35	0.51±0.68	9.80±1.15	0.48±0.05
S1 F (n=13)	20.1±2.1	12.08±1.50	0.60±0.07	11.53±1.80	0.57±0.88	11.15±1.52	0.55±0.07	10.72±1.39	0.53±0.06
Total (n=64)	20.4±4.4	11.53±1.57	0.57±0.07	10.74±1.64	0.53±0.08	10.39±1.42	0.52±0.07	9.99±1.24	0.50±0.06
M (n=46)	20.8±4.9	11.25±1.7	0.56±0.08	10.53±1.74	0.52±0.08	10.29±1.51	0.51±0.07	9.98±1.40	0.49±0.07
S2 F (n=14)	20.1±2.1	11.76±1.05	0.58±0.05	11.12±1.18	0.55±0.05	10.92±1.37	0.54±0.06	10.75±1.48	0.53±0.07
Total (n=60)	20.85±4.3	11.37±1.58	0.56±0.07	10.67±1.64	0.53±0.08	10.43±1.50	0.52±0.07	10.16±1.44	0.50±0.07

+ Mean (±) SD proactive time to hit twenty light sequences

*Threshold: Mean proactive reaction time for 20 lights

S=Schedule, T=Trial

Table 2. Reliability (Coefficient of variation, CV), Intraclass correlation coefficient (ICC), Pearson's r, Standard error measurement (SEM) and Bonferroni post hoc comparisons between trials.

S1						S2				
TRIALS	*Typical Error CV	ICC	Pearson's r	Bonferroni Adjustment	SEM	*Typical Error CV	ICC	Pearson's r	Bonferroni Adjustment	SEM
1-2	7.30	0.74	0.76	P=0.001	9.1	6.21	0.74	0.82	P=0.001	7.8
2-3	7.14	0.75	0.77	P=0.255	7.4	6.43	0.80	0.83	P=0.803	6.6
3-4	4.94	0.86	0.87	P=0.004	5.7	4.76	0.81	0.89	P=0.019	5.1

*95% confidence interval) for all trials

Figure Legends

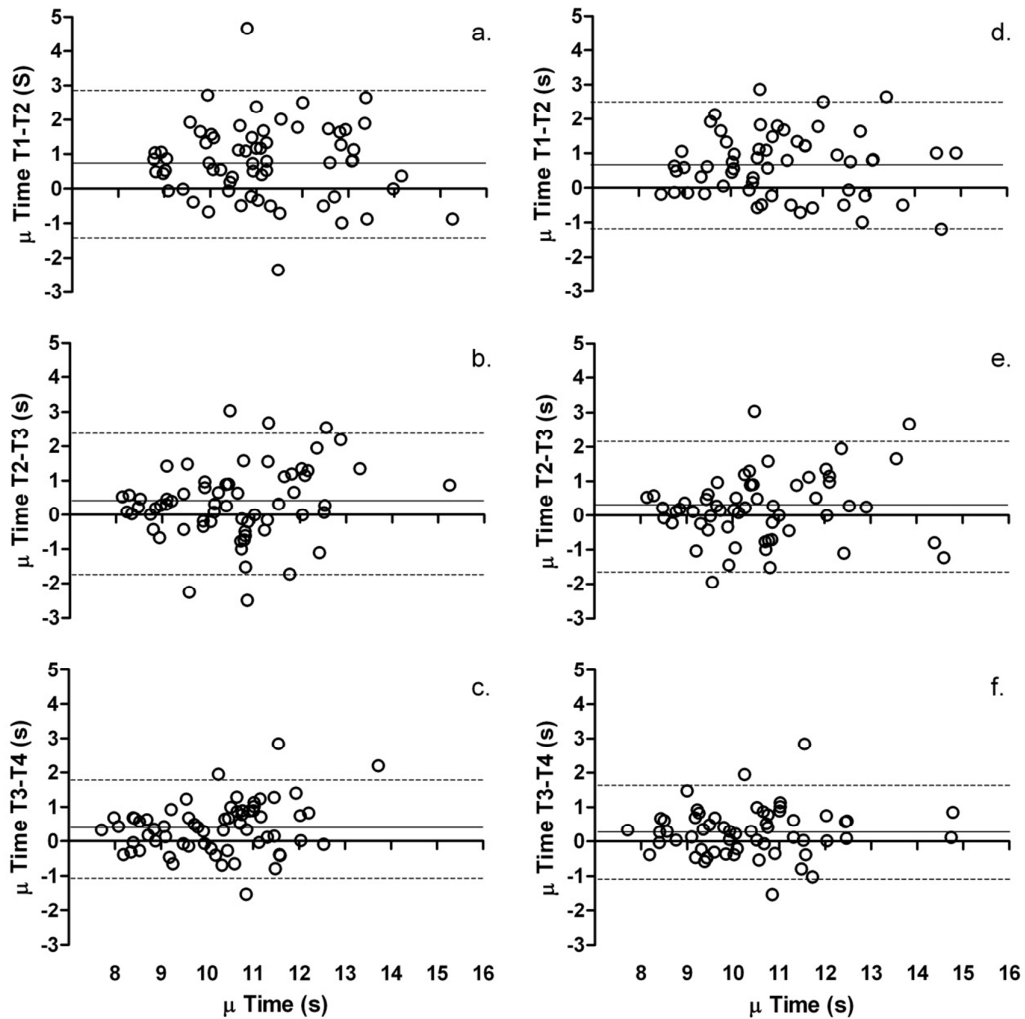


Figure 1: Bland Altman plots showing differences between tests against each individual mean for Schedule 1; (a) *trial 1-trial 2*, (b) *trial 2-3* and (c) *trial 3- trial 4*, and Schedule 2; (d) *trial 1-trial 2*, (e) *trial 2-3* and (f) *trial 3- trial 4*. Solid lines represent mean bias; dashed lines represent 95% limits of agreement.